Research Proposal

On

IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE (TPM) FOR IMPROVEMENT OF OVERALL EQUIPMENT EFFECTIVENESS (OEE) IN MANUFACTURING INDUSTRIES

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Abstract

Frequent machine breakdowns, low plant availability, increased rejection are a great threat to increase operating cost and lower productivity. The objective of the work is to enhance the Overall Equipment Effectiveness (OEE) in manufacturing companies through the implementation of Total Productive Maintenance (TPM). The company has to suffer due to lower availability of machines as a result of breakdowns. Comparison of OEE between before and after implementation of TPM can provide the much needed force to improve the maintenance policy.

The global marketplace is highly competitive and organizations who want to survive long term, have to continuously improve , change and adapt in response to market demands . Improvements in a company's performance should focus on cost cutting, increasing productivity levels, quality and guaranteeing deliveries in order to satisfy customers. Total Productive Maintenance (TPM) is one method , which can be used to achieve these goals. TPM is an approach to equipment management that involves employees from both production and maintenance departments. Its purpose is to eliminate major production losses by inintroducing a program of continuous and systematic improvements to production equipment.

This research work reviews the Pillars of Total Productive Maintenance (TPM), TPM implementation methodology and the contribution of TPM towards improving manufacturing performance.. It will also focus on calculating the Overall Equipment Effectiveness (OEE) in a couple of industries as case studies in India. The relationship between various TPM implementation dimensions and manufacturing performance improvements have been evaluated by applying OEE. The study establishes that focused TPM implementation over a reasonable time period can strategically contribute towards realization of significant manufacturing performance enhancements.

The primary goal of TPM program is to change the culture of the company maintenance policy by participating all employees toward the maintenance system of the company. It aims to reduce unplanned stoppage, breakdowns, accidents and losses obstructing equipment effectiveness. In most of the Indian industries maintenance is considered as step motherly attitude of activity. Therefore by implementing TPM the industries can increase their equipment effectiveness and productivity.

Total Productive Maintenance (TPM) is an equipment improvement effort, bringing maintenance and production departments together to prevent equipment downtime and failures. The fast rate of acceptance of TPM indicates that the practitioners always have the thirst for improvement in equipment performance. The Overall Equipment Effectiveness (OEE) measure is the basic requirement in a manufacturing industry improvement approach of TPM effort. Manufacturing organization can use the OEE calculations to know, how

effectively the equipment is running. An accurate OEE percentage indicates whether the equipment is running at optimum capacity and producing quality output or experiencing unnecessary downtime. Therefore studies related to OEE and enhancing equipment performance is a major concern of this research work. This study investigates and makes use of OEE performance measurement . The OEE measure basically consists of three factors namely Availability, Performance efficiency and Quality rate .

Today's successful manufacturing organisations require a significant competitive advantage , hence the need of the hour is to implement and develop a Total Productive Maintenance (TPM) strategy in the manufacturing industries.

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 Introduction

New approaches in modern service and manufacturing industries have been floating around, developed and implemented so as to survive in the dynamic and fierce competitive system that are becoming ever more complex. The need for driving down costs, integrating every activities and available resources of a company, empowering the employee to make decision, eliminating waste generated by failure across the value adding process, shortening of production lead time and delivery of quality assured services and products have been given due attention as they are the necessity to secure a sound future within an ever-changing market and to be open to all market and technology driven opportunities. To meet these needs, one of the new techniques in maintenance area that is developed in Japan to support TQC and JIT is Total Productive Maintenance (TPM).

Even though, many management personnel consider maintenance as expense and second rated activity, presently, there is a gradual shift in thinking as companies began to identify the role of maintenance and it is also well accepted that maintenance is one of the main potential areas to use as a competitive advantage. Currently, the concept of TPM in the Indian Manufacturing Industries is the critical missing concept in successfully achieving not only world class equipment performance, but also a powerful new means in improving overall company performance.

Equipment performance plays an important role in every industrial organization. Maintenance is concerned with the performance of a wide variety of activities needed for ensuring the smooth working of equipment and facilities. The philosophies like Total Quality Management (TQM), Just-in-time (JIT), Flexible manufacturing systems (FMS) etc. have led to a comprehensive technique known as Total Productive Maintenance (TPM) (Robinson and Ginder 1995).

The present research mainly deals with the principles and concepts of Total Productive Maintenance based on literature review and assess the existing maintenance activities of the industries in line of TPM. The work is organized in such a way that the results of the conducted study will be presented in comprehensible way.

The research work commences with the introduction part that discusses the background, objectives, and the significance of the research. Structure of the Thesis is given in the following pages chapter wise

“TPM is considered by many writers to be an indispensable contribution to lean production supporting just-in-time (JIT) manufacture and Total Quality Management (TQM), and has been shown as an essential pillar alongside JIT and TQM for companies seeking world-class manufacturing status.” (Bamber, Sharp and Hides 1999:162).

Therefore, an assessment of the impact of Total Productive Maintenance (TPM) on manufacturing performance by the researcher is appropriate and essential for the Indian industries and of course ultimately the economy of the country.

1.2 Overview

Industries now a days are becoming incompetent in national as well as international markets. The reason for this may be that the management system of the industries does not allow the industries to become more competitive. Maintenance is one of the areas to be given due consideration in modern management to increase machine productivity and to produce quality products as well. The modern business world is exploiting better mechanisms to be competitive the last thing the industries need, if they are to provide better product to get in their own way to develop suitable system for the success of their business.

However, through effective maintenance management system, there is a way for the industries to enhance their capacity and to provide better product than they are doing at present. It is by developing and implementing a Total Productive Maintenance System covering the entire life of the equipment, spanning all equipment related fields (planning, use, maintenance, etc.) in the company and with the participation of all employees from top management down to frontline operators.

Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. The dual goals of TPM are *zero breakdowns and zero defects*; this obviously improves equipment efficiency rates and reduces costs.

Generally the study will focus on assessing the existing maintenance system of the industry to investigate potential area of improvement so as to develop and implement the Total Productive Maintenance to the best achievement of the objective and the best performance of all the activities.

1.3 Problem Statement

Manufacturing Industry is one of the economy driven companies in India and the machineries in the modern times are almost computerized except very few. The company is capable of producing different items through new and computerized machineries but what is distressing is that the company has been operating under its capacity due to high rate of unplanned failure. In addition to this problem, the machinery that is failed may be out of function for a long period of time attributable to shortage of spare parts, poor controlling system and reporting system prevailing in the industry.

Generally, the maintenance system of the industry is based on poor integration of all functions and processes in the organization, which results in:

-High maintenance cost
-Less availability and reliability of equipments

-High total maintenance hour and man hour.
-Frequent failure of machineries
-Low profit
-Low production
-Workers dissatisfaction

As the country is having high demand of industrial products, enhancing the performance of the industry through implementing , well developed and organized maintenance system will not only help the industry to have efficient way of maintaining its different machineries but also it contributes its experience for the similar companies towards providing high quality products. Furthermore, it enables the industry to keep the level of spare parts in stock at a minimum level for effective maintenance and for savings of foreign currency.

To achieve a competitive advantage, organizations have implemented various world-class manufacturing techniques / strategies . One of these is TPM, which is part of lean manufacturing (Rubrich & Watson, 2000).

TPM goals are :

*Zero breakdowns
*Zero abnormalities
*Zero defects
*Zero accidents (Nakajima, 1989)

The path to this ideal situation is continuous improvement that requires total commitment of everyone in the organization, from operators to top management . With this in mind, the researcher has therefore focused on this research topic with a view to determine whether the TPM concept is a viable route to follow or another temporary solution. This leads to the question, which constitutes the main problem of this research work.

Main Problem :

*What is the impact of Total Productive Maintenance (TPM) on manufacturing performance at the industry proposed for the study to be carried out ?

In order to develop a strategy to conduct this research in a systematic manner, a number of sub-problems were highlighted to enable the researcher to find an appropriate solution to the main problem.

Sub-Problems :

*What does literature reveal about the impact of TPM on the manufacturing performance of the organization ?

*To what extent has TPM been implemented in the organization ?

*What is the extent of the cost savings as a result of TPM implementation in the organization ?
*What will enhance the impact of TPM on fast delivery and on-time delivery in the organization ?

Hence, this thesis aims at addressing and improving the maintenance system of the industry to clearly scrutinize the hidden factors, which hinder the capacity of the industry.

1.4 Objectives of research

Based on observed problems, the study mainly focuses on dealing with the way that the manufacturing industry enables to improve the existing maintenance system of the company to have better capacity utilization and to enhance the effectiveness of its equipments. Hence, the thesis will try to fulfill the following objectives.

The objectives of research are :

*To Identify the elements of TPM and its guidelines for overall plant performance .

*To establish the influence of TPM on productivity, employee development, quality improvement and organizational change.

*To analyse the past and the current status of TPM on manufacturing performance measurements.

*To understand the performance of the equipment in terms of what is being achieved in overall equipment efficiency and what is the reason for non-achievement.

1.5 Scope and limitations of research

The Empirical study is based on the available data, questionnaire, interview and visit. The available data is taken for one year only due to poor recording and reporting system prevailing in the company. Further more, the author couldn't find a single company, which has experienced in the implementation of TPM in the country to share the experience for Total Productive Maintenance development program for the company. Hence, the author persuaded himself to rely on the literature and the experience of foreign companies where TPM implementation yielded results.

1.6 Significance of research

The study will have significant contributions to the company by having well established maintenance system that facilitates it to provide better services to its customer. Further more; the study can be used with small adaptation in similar manufacturing industries. The study is also valuable for further and better research.

1.7 Definitions of key concepts

For the purpose of the study, the following meanings are associated with concepts in the title and the problem statement

1.7.1 Autonomous maintenance

Autonomous maintenance is the best practice of operators taking ownership of their equipment and sharing the responsibility of its maintenance with the maintenance department (Nakajima, 1989). The consequence of a maturing autonomous maintenance program is the transfer of routine maintenance skills from the technician to the TPM operators (Rich, 1999:312). This process of transition frees an element of the maintenance role each time these skills are passed from technician and includes the transfer of routines that hold low levels of value-add when this type of work is passed on to operators who benefit from improved ownership of the production process when they are empowered through greater control.

1.7.2 Continuous improvement

This means improving performance with many small, incremental improvement steps . In Japan, continuous improvement is known as Kaizen and involves everyone. It implies a never-ending cycle of repeatedly questioning and requisitioning of the basic workings of an operation (Russel & Taylor, 2003).

1.7.3 Total Productive Maintenance (TPM)

TPM's strict definition has five steps, (Nakajima, 1989):

*Maximizing equipment effectiveness through optimization of equipment availability, performance, efficiency and product quality.

*Establishing a maintenance strategy (level and type of classical preventive maintenance) for the life of equipment.

*Includes all dependents such as the planning, the user and the maintenance department.

*Involving all the staff members from top management to shop floor workers.

*Promoting improved maintenance through small-group autonomous activities.

TPM also encourages radical changes such as:

*Flatter organizational structures, i.e. fewer mangers and empowered teams.

*Multi-skilled workforce.

*Rigorous re-appraisals of the way things are done, often with the goal of simplification (Liker, 2004).

TPM has two main aspects:

*A structured approach which uses a number of tools and techniques such as Kaizen, 5S, reactive, preventative, reliability-centered and predictive maintenance to achieve very effective plants and machinery and to measure its effectiveness .

*A philosophy, which is based upon the empowerment and encouragement of factory floor-based personnel from all areas (Davis & Wilmott, 1999) .

1.7.4 5S method of equipment maintenance

This is a pre requisite for the implementation of TPM because of the order and logic it brings to the workplace. 5S is defined as the best practice of implementing and maintaining good and structured house keeping. It consists of:

*getting rid of unnecessary items .

*a place for everything in its proper place .

*establishing housekeeping standards

*maintaining standards in a disciplined way. (Rubrich and Watson, 2000) .

1.7.5 Lean manufacturing

This is a way of thinking that focuses on making the product flow through value-adding processes without interruption (one- piece flow) , a “pull” system that cascades back from customer demand by replenishing only what the next operation takes away at short intervals, and a culture in which everyone is striving continuously to improve (Womack and Jones, 2003) .

1.7.6 Just-In-Time (JIT)

Just-in-time is defined as a set of principles, tools and techniques that allow a company to produce and deliver products in small qualities, with short lead times, to meet specific customer needs (Liker, 2004:23) **.**

1.7.7 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness is defined as a gauge system on equipment that measures quantities such as uptime, units produced, and sometimes even the production speed. This technique works to eliminate the six big losses indicated by Nakajima, as down time (caused by equipment failure, set-up and adjustment), speed losses (owed by idling, minor

stoppage and reduced speed) and defects (caused by process defects and reduced yield) (Nakajima, 1989) .

1.7.8 Total Quality Management (TQM)

Total Quality Management is defined as a business-wide philosophy which includes changing attitudes, working practices, values and the overall method of operation of the company. Its overall aim is to improve continuously the operating performance of the business, thus providing better customer service and increased profitability (Davis, 1955:11) .

1.7.9 Productivity

Productivity is a measure of the effective use of resources, usually expressed as the ratio of output to input. A productivity ratio can be computed for a single operation, department, an organization or an entire country.
For non-profit organizations, higher productivity means lower costs,
For profit-based organizations, productivity is an important factor in determining how competitive a company is .

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to TPM

Maintenance is a profession devoted to keep the factory running in the best possible shape, making equipment reliable, productive, and secure to operate.

The maintenance function has historically been thought of as a necessary cost of doing business. However, new technologies and innovative practices have positioned the maintenance function to be an integral part of the overall profitability of many businesses. Modern maintenance techniques and practical approaches have the potential for significantly increasing competitive advantages in the global market. Just as the finely meshed gears of machinery must work together for the machine to perform its function, Production, Safety, Design Engineering, other team members, and Maintenance must work together to achieve true excellence.

The challenge for today's maintenance managers and reliability professionals, and all those involved in the maintenance profession, is to capture these opportunities. This requires establishing standards for maintenance and reliability practices, creating an appropriate information system to collect facts and build enthusiasm, and initiating enabling action plans. The responsibility of keeping our equipment and facility in optimal working conditions is not that of a small group of Engineers and Technicians, but every individual in the whole organization.

Everyone in the organization will reap the benefit of this optimal condition and therefore all should be empowered to learn and intervene more in the vital process of preservation. TPM is exactly the discipline that will allow us to achieve such optimal level of success.

According to Nakajima (1989), the word “total” in “total productive maintenance” has given three meanings that describe the principle features of TPM as :

*Total effectiveness indicates TPM’s pursuit of economic efficiency or profitability which includes productivity, cost, quality, delivery, safety, environment, health and morale.

*Total maintenance system includes maintenance prevention and maintainability improvement as well as preventive maintenance. It refers to “maintenance-free” design through the incorporation of reliability, maintainability, and supportability characteristics into the equipment design .

*Total participation of all employees includes autonomous maintenance by operators through small group activities which promote planned maintenance through “motivation management” .

In essence, TPM seeks to integrate the organization to recognize, liberate and utilize its own potential and skills (Lee, 2002) .

2.2 History of TPM

The father of TPM, Seiichi Nakajima, in his well known book, *TPM Development Program*, has pointed out that the origin of TPM traced back to 1951 when Preventive Maintenance was introduced in Japan (Osama Taisar R.Almeanazel, 2010). He referred the time prior to 1950 as the “breakdown maintenance” period. The Japanese has developed TPM to support their lean manufacturing system based on Preventive Maintenance, Corrective Maintenance and Maintenance Prevention concepts and methodologies that was originated and developed in the U.S.A.

Using Preventive Maintenance, the service life of the plant and equipment can be prolonged by reconditioning the equipment before adverse conditions lead to failure. In this concept the operators were not empowered in maintaining minor activities rather he only operates the equipment (Ravikant V. Paropate, Vol. No. 6 Issue No. 2). This requires more maintenance personnel which leads Nippondenso Co., the first company to be awarded the Distinguished Plant Prize (PM Prize) in 1971 for developing and successfully implementing TPM for reducing the maintenance men. To decide that the routine maintenance of equipment should be carried out by the operators to reduce the maintenance personnel which is one of the features of TPM? The Japanese accepted the concept of Corrective Maintenance (CM) system in 1957 which was expanded from Preventive Maintenance (PM) to redesign equipment with design weakness to eliminate equipment failure and to improve maintainability. They also imported Maintenance Prevention (MP) in 1960 to incorporate the modification of the weakness of the existing equipment in the design of the new equipment to pull off maintenance free equipment (Hemant Singh Rajput, Pratesh Jaswal, Vol. 2 Issue 6) .

Preventive Maintenance along with Corrective Maintenance and Maintenance Prevention gave birth to Productive Maintenance. Then in the 1970s, TPM evolved to a strategy focused on achieving Productive Maintenance efficiency through a comprehensive system based on total employee participation which was the basic concept of TQM. It was at this time that “Total” was added to Productive Maintenance as the challenges of intense international competition require companies to deal with system in 'total'. It is a kind of marriage between PM and TQM. According to Ross Kennedy, the modern quality approach of "prevention at source" was translated to the maintenance environment through the concept of TPM resulting in not only superior availability, reliability and maintainability of equipment but also significant improvements in capacity with a substantial reduction in both maintenance costs and total operational costs. TPM is based on "prevention at source" and is focused on identifying and eliminating the source of equipment deterioration rather than the more traditional approach of either letting equipment fail before repairing it or applying preventive / predictive strategies to identify and repair equipment after the deterioration has taken hold and caused the need for expensive repairs. Today the concept of TPM is widely accepted and has been implemented in various industries. However, the author has never encountered one single Indian industry that tries to exploit the benefits of TPM, while conducting the research (Ravikant V. Paropate, Vol. No. 6 Issue No. 2).

2.3 World-class manufacturing and TPM

During the last decade, many manufacturing companies have made extensive use of bench marking activities to determine "best in class" performance for management practices (Todd, 1995). These management practices are termed world-class manufacturing concepts and are :

*Total Quality Management (TQM)

*Total Productive Maintenance (TPM)

*Just-In-Time Production (JIT)

*Total Employee Involvement (TEI)

*Continuous Quality Improvement (CQI)

These concepts cover all the components of an effective manufacturing management system.

However the concepts of *Total Employee Involvement (TEI) *Continuous Quality Improvement (CQI) are not covered in detail in this thesis work .

2.3.1 Relationship between TPM and TQM

According to Venkatesh J (1996) TQM and TPM has many similarities and differences that both aiming at maximizing the efficiency of the man/machine system through eliminating wastes, involving employees and preventing problems to deliver quality service and product to delight the customer. Like TQM, which is companywide total quality control, TPM is equipment maintenance performed on a companywide basis. In order to achieve the TQM target of "building quality into the product during the manufacturing process", it is necessary to perform full TPM activities and improve human resources so that "the quality can be built into the products thorough the equipment. Many of the tools such as employee empowerment, benchmarking, documentation, etc. used in TQM are used to implement and optimize TPM.

Following are the similarities between the two.

1. In both cases leadership commitment is required for the implementation.
2. Employees must be empowered to initiate corrective action, and
3. Changes in employee mindset toward their job responsibilities must take place as well.

Even though TQM and TPM have some features in common, there are also issues that differentiate them. The main differences is that TPM concentrate on the machine, process and slow trends, while TQM deals with Quality tools and management of fast changes. The differences between them are presented in table 2.1 shown below.

Table 2.1: The differences between TQM and TPM

Category	TQM	TPM
Object	Quality(Output and effects)	Equipment (Input and cause)
Means of achieving the goal	Systematize the management. It is software oriented	Realization of what the equipment condition must be. It is hardware oriented
Cultivation and education of employees	Education focusing mainly on the management techniques (QC technique)	Education centering on the Organization-developed technology (Equipment / maintenance technologies)
Small group of activities	Voluntary circle activities	Integrating the activities based on top-down and bottom-up

2.3.2 Relationship between RCM and TPM

The Reliability Centered Maintenance (RCM) process was evolved within the civil aviation industry to fulfill precise need to maintain 'basic equipment conditions" where looseness, contamination or lubrication problems are not allowed. As a result, high standard of training, high skill level of operator's and maintenance man are compulsory where most manufacturing, road transport and mining industries fail to have such capacity. This undermines the application of RCM in most of the industries. For this reason, the application of TPM as a company wide improvement strategy is highly advisable to ensure:

- basic equipment conditions are established and
- equipment - competent operators are developed

The other key difference between RCM and TPM is that RCM is promoted as a maintenance improvement strategy whereas TPM recognizes that the maintenance function alone cannot improve reliability. Factors such as operator 'lack of care' and poor operational practices, poor 'basic equipment conditions', and adverse equipment loading due to changes in processing requirements (introduction of different products, raw materials, process variables etc) all impact on equipment reliability. Unless all employees become actively involved in recognizing the need to eliminate or reduce all "losses" and to focus on 'defect avoidance' or 'early defect identification and elimination 'failures will never be cost effectively eliminated in a manufacturing or mining environment (Manu Dogra, Vishal S Sharama, 2011)

2.4 Maintenance concepts

A maintenance concept is defined as the set of various maintenance interventions (preventive, corrective, reliability-centered, condition-based, etc.) and the general structure in which these interventions are brought together.

Some of these maintenance concepts are explained as follows (Wireman, 1991) :

2.4.1 Preventive Maintenance (PM)

In this type of maintenance, items are replaced or restored to their optimal working condition before a failure is allowed to occur. This amy be based on scheduled, time-based or condition-based PM. The schedule is drawn up on the supplier's recommendation, which usually only considers limited knowledge of the actual conditions. Therefore, it is better to draw from experience.

2.4.2 Reliability-Centered Maintenance (RCM)

RCM is a process used to decide what must be done to ensure that any physical system or process continues to accomplish whatever its users want it to do. What is expected is defined in terms of primary performance parameters such as, output, throughput, speed, range and capacity. Sometimes, the RCM process defines minimum standards, which the users can tolerate in terms of risk (relating to safety and adverse environmental-impact), quality (in terms of precision, accuracy, consistency and stability), control, comfort, economy and customer service .

RCM operates through the use of analysis techniques such as:

*Failure Modes Effect Analysis (FMEA) *Cause and effect analysis *Risk analysis

Failure management options include PM, predictive maintenance, and run-to-failure, which can result in changing the design of the system and / or the way it is operated (Moubray, 2000) .

2.4.3 Condition-Based Maintenance (CBM)

Also called predictive maintenance, CBM forecasts failures through analysis of the condition of the equipment. A number of monitoring techniques are used such as vibration monitoring, thermography, oil analysis and ferrography .

Each of these methods is designed to detect a specific category of faults. For example , vibration monitoring can detect wear, imbalance misaligned components, loosened assemblies or turbulence in a plant with rotational or reciprocating parts. The design may be modified to achieve omproved reliability, enhanced maintainability, minimum maintenance resource requirements and so even eliminate the need for routine maintenance.

2.5 Maintenance performance indicators

According to Campbell and Jardine (2001), the commonly used maintenance performance indicators are measures of :

*Equipment performance such as availability, reliability and OEE .
*Process performance such as the ratio of planned and unplanned work, as well as of schedule .
*Cost performance such as labor and material costs of maintenance .

2.6 TPM targets

TPM targets should reflect the ongoing transactions with the customer (quality, cost and delivery criteria) as well as ongoing measures which affect the productivity within the factory (productivity, safety and morale) . These issues are termed "PQCDSM" (Nakajima, 1989) .

The goal of TPM focuses on improving corporate culture through improvement of human resources and plant equipment. The Japan Institutes of Plant Maintenance (JIPM) has put forward the five goals of TPM which are the minimum requirements for the TPM development (Hemant Singh Rajput, Pratesh Jaswal, Vol. 2 Issue 6) .

1. Improving equipment effectiveness.
2. Improving maintenance efficiency and effectiveness.
3. Early equipment management and maintenance prevention.
4. Training to improve the skills of all people involved.
5. Involving operators in routine maintenance.

2.6.1 Improving Equipment Effectiveness

Equipment effectiveness is a measure of the value added to production through equipment. This goal is to increase equipment effectiveness so each piece of equipment can be operated to its full potential and maintained at that level. Nakajima describes in his book that TPM maximizes equipment effectiveness though two types of activity to insure that the equipment performs to design specifications which is the true focus of TPM (Ravikant V. Paropate, Vol. No. 6 Issue No. 2).

-*Quantitative*: increasing the equipment's total availability & improving its productivity within a given period of operating time.

-*Qualitative*: reducing the number of defective products, stabilizing & improving quality.

Although the equipment must operate at its design speed, produce at the design rate, and produce a quality product at these speeds and rates, there are factors which might obscure efficient utilization of the equipment. Examining, identifying and eliminating all losses which obscure the efficiency of the equipment will increase the efficiency of the equipment. The concept of zero breakdowns And zero defects are inevitable to maximize equipment effectiveness. These equipment losses include: Equipment downtime loss, Equipment performance loss, and defect loss (Osama Taisar R.Almeanazel, 2010).

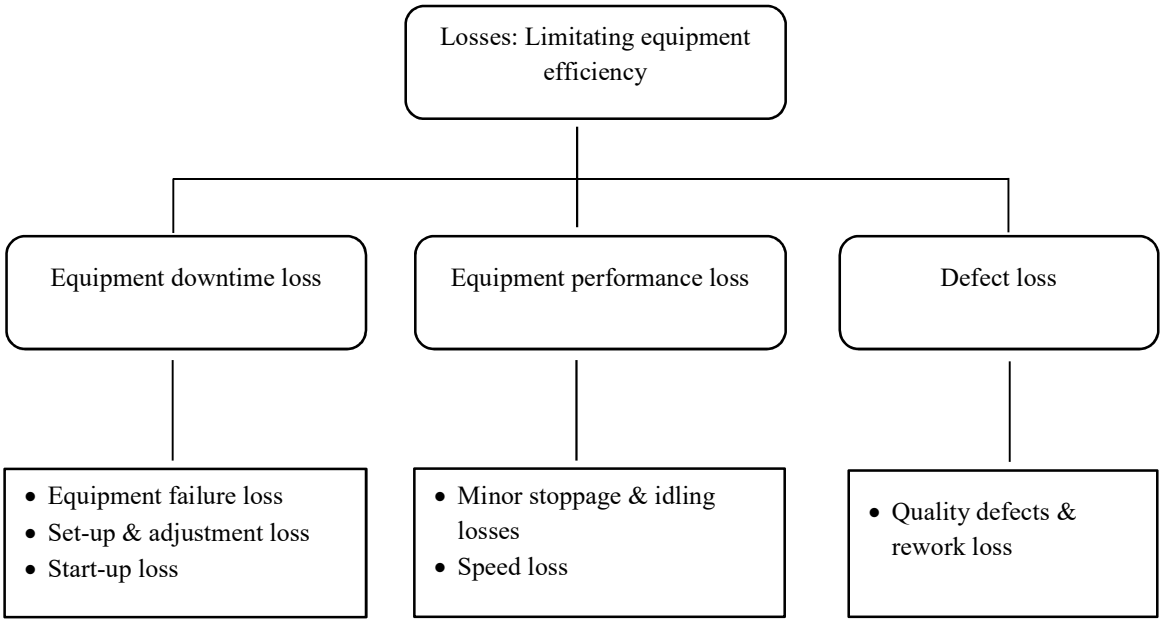

Figure 2.1 : Major losses limiting equipment efficiency

Various equipment losses can be quantitatively calculated through measuring equipment effectiveness that ties the '6 major losses' to three measurable.

What is Overall Equipment Efficiency (OEE)?

OEE is a tool that combines multiple manufacturing issues and data points to provide information about the process. It is an all-inclusive benchmarking tool that serves to gauge the various subcomponents of the manufacturing process (i.e., availability, performance and quality) - and used to measure actual improvements on 5S, Lean Manufacturing, TPM, Kaizen and Six Sigma. When using OEE with these management systems the benefits become tangible and noteworthy .

After all factors are taken into account, the OEE result is converted (transmuted) in percentage. The results (in %), therefore, can be regarded as a preview of the existing production efficiency of a particular line, cell or machine.

As we all know, manufactured goods are a result of a complex production process - and without the proper measuring tools and formula, expect your business to run blindly even in the light of day. Having the right metrics, OEE provides you a window to analyze outoftheordinary issues and gives you an established framework for improving the whole manufacturing process.

There are dozens of formulas, systems and metrics being used to improve the whole manufacturing process, but only OEE correctly reduces complex production problems into

simple, easy to follow steps in handling data and information. The OEE tool helps to methodically improve the process using basic measurements.

The good thing about using OEE is that this particular measuring tool cannot be manipulated. OEE is a very simple metric that immediately indicates the current status of a manufacturing process. Somehow it also becomes a multifaceted tool allowing to understand the effect of the various issues in the manufacturing process and how they affect the entire process.
The biggest advantage of OEE is that it allows companies to have separate business functions by applying/using a single, easy to understand formula. OEE is by far the most effective benchmarking tool in making sound management decisions.

Useful Formulae:

OEE = Actual output / Theoretical maximum output
OEE = Availability Ratio x Performance Ratio x Quality Ratio

***Availability Ratio :** The share of the actual production time and the planned production time. All planned stops and breakdowns will reduce the availability ratio, including setup times, preventive maintenance, breakdowns and lack of operators. The only time that you may choose to deduct from the availability ratio is lack of orders.

***Performance Ratio :** Loss of production due to underutilization of the machinery. In other words, losses are incurred when the equipment is not run with full speed. Short, unregistered, stops may affect the performance ratio as well.

***Quality Ratio :** The amount of the production that has to be discharged or scrapped. It is a significant performance indicator in TPM which enables one to know how much the equipment is utilized to the fullest. A high level of equipment effectiveness can be achieved only when all three rates are high.

2.6.2 Improving Maintenance Efficiency and Effectiveness

This goal focuses on insuring that maintenance activities that are carried out on the equipment are performed in a way that it is cost effective. This involves the identification of the nature and level of preventive maintenance required for each piece of equipment, the creation of standards for condition based maintenance, and the setting of respective responsibilities for operating and maintenance staff to insure lean maintenance, with no waste in the maintenance process.

Maintenance staff must develop and carry out the following activities:

-Eliminate deterioration resulting from inadequate lubrication and cleaning.
-Develop and carry out preventive actions and general breakdown services.
-Analyze every breakdown to reveal weakness in the equipment.
-Modify equipment to improve its maintainability and lengthen its life.
-Developing an accurate database for each piece of equipment’s maintenance history.

Maintenance staff typically moves to a more facilitating and supporting role where they are responsible for the training of operators, problem diagnosis, and devising and assessing maintenance practice. The operating staff takes on the "ownership" of the facilities and their general care. The maintenance staff and the operator need to understand and cooperate each other which is the main feature of the TPM to maximize maintenance efficiency.

2.6.3 Early Equipment Management and Maintenance Prevention

The aim of this goal is develop maintenance free equipment through carefully studying the maintenance and the failure causes of the existing equipment and incorporating at the design stage. This will lead to the improved maintainability of the equipment. TPM attempts to track all potential maintenance problems back to their root cause so that they can be eliminated at the earliest point in the overall design, manufacture and deployment process.

2.6.4 Training to Improve Operating and Maintenance Skills

One of the main goals of TPM is to equip the operator and the maintenance personnel with appropriate skills and knowledge. Providing the proper level of training insures that the overall equipment effectiveness is not negatively impacted by any employee who did not have the knowledge or skill necessary to perform job duties. In the implementation of TPM this will create to have multiskilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. In TPM the company must invest on training employees in the use of their equipment.

2.6.5 Involving Operators in Routine Maintenance

Autonomous maintenance by operators is one of the most unique features of TPM. This is to allow the people who operate equipment to take responsibility for, at least some, of the maintenance tasks. This goal finds maintenance tasks related to the equipment that the operators can take ownership of and perform. This enables the operators to keep his equipment in good condition by himself and to feel a sense of ownership. Maintenance activities that were formerly performed by the operator can then be redeployed in more advanced maintenance activities such as predictive maintenance or reliability focused maintenance activities.

2.7 Measurement of TPM effectiveness

From a generic perspective, TPM can be defined in terms of Overall Equipment Effectiveness (OEE) . The goal of TPM is to maximize equipment effectiveness. OEE provides an effective way of measuring and analyzing the efficiency of a single machine / cell or an integrated manufacturing system . OEE is also used as a driver for improving performance of the business by concentrating on quality, productivity and machine utilization issues. It is aimed at reducing non-value adding activities, often inherent in manufacturing processes.

2.7.1 Overall Equipment Effectiveness (OEE)

Firstly the OEE measure can be used as a benchmark for measuring the initial performance of a manufacturing plant in its entirety. In this measure, the initial OEE measure can be compared with the future OE values, thus quantifying the level of improvement made.

Secondly, an OEE value, calculated for one manufacturing line, may be used to compare line performance across the factory, thereby highlighting any poor line performance.

Thirdly, if machines process work individually, an OEE measure can identify which machine performance is worst and therefore indicate where to focus TPM measures.(Nakajima, 1989) .

2.7.2 Six big losses

Chronic and sporadic disturbances in the manufacturing process result in different kinds of waste or losses. It is a bottom-up approach where an integrated workforce strives to achieve overall equipment effectiveness by eliminating the six big losses (Nakajima, 1988) .

These six big losses are grouped into three major categories :

*Downtime *Speed losses *Defect losses

Nakjima (1988) defines these big losses as shown in the table 2.2 below:

Table 2.2 : The Six big losses

Loss categories	Six big losses
Downtime (Lost availability)	*Equipment failures *Set-up and adjustments
Speed losses (Lost performance)	*Idling and minor stoppages *Reduced speed operation
Defect losses (Lost quality)	*Scrap and rework *Start-up losses

Downtime : Downtime refers to the time when the machine should be running but stands still. Downtime includes two main types of losses namely *Equipment failures *Set-up and adjustments losses

***Equipment failures :** These losses of operating time result from the deterioration of equipment, and sudden failures in the operating and control mechanisms of equipment. This form of lost time is compounded by the need to keep or procure spaces and anytime the factory labor is not utilized whilst the restoration of the machine takes place.

***Set-up and adjustments losses :** These losses are created through the procedures, methods and technology required to change a machine from one product to another . The production schedule will dictate the number of changes required. However the actual process of changing the machine over is the loss which must be minimized.

Speed losses : A speed loss is when the equipment is not running at its maximum designed speed. Speed losses include two main types of losses *Idling and minor stoppages *Reduced speed operation

***Idling and minor stoppages :** When a machine is not running smoothly and at a stable speed, it will lose speed and obstruct a smooth flow. The idling and stoppages in this case are not caused but technical failures but by small problems such as parts that block sensors. Although the operator can easily correct such problems, frequent halts can dramatically reduce the effectiveness of the equipment.

***Reduced speed operation :** This refers to the difference between the actual operating speed and the equipment's designed speed (also referred to as nameplate capacity). The goal is to eliminate the gap between the actual speed and the designed speed. Significant losses from reduced speed operation are often neglected or underestimated.

2.8 Pillars of TPM

The Japan Institute of Plant Maintenance propose the introduction of TPM program is based on the implementation of a series 8 pillars of TPM in a systematic way to optimize plant and equipment efficiency by creating perfect relationship between man and equipment. The common structure of TPM is shown in the figure 2.4 below :

TPM Implementation Process : TPM Implementation Process involves 8 pillars of TPM at 6 levels as detailed in the table 2.3 below:

Table 2.3 : TPM Implementation Process: Pillars of TPM implementation process

Pillar	Level	Action
Autonomous Maintenance	1	Preparation of the employee for training of machine operation
		Initial cleaning up of the machines in all the departments
	2	Taking action at the source of problems such as breaking of belts etc.
		Tentative cleaning standards for the machines
	3	General Inspection
		Preparing the operators in general inspection to identify general inspection items
	4	Autonomous Inspection
		Re- examine from Zero failure point of view + Specific visual control method for the machines
	5	Standardization of the inspection interval for all machines
		---
	6	Implement the above activities by Deming PDCA Cycle

Kaizen	1	Select model of the machine
		Setting improvement goal for the machine
	2	Confirm the present losses on the machine
		Organization the project teams
	3	Mapping out the improvement plan

	4	Implementation of Kaizen

	5	**Improvement activity**
		Confirm effects
	6	**Improvement activity**
		Analyze different methods
Planned Maintenance	1	Create and update equipment ledger
		Create evaluation criteria
		Define failure ranks for the machines
	2	Restore deterioration
		Improve weakness

	3	Executing PM
		Executing CM

	4	Automate maintenance system
		Introducing performance indicator
		Keeping and using maintenance records
	5	Automate the operation system

	6	Standardize every activity of industry
		implement PDCA cycle

Quality Maintenance	1	Predict accidents in factories
		Clean every tools in factories
	2	---
		Check smooth operation of measuring devices
	3	---
		Use right measuring methods
	4	---
		Build material and equipment not to generate any defect. Set standard
	5	---
		Revise the standards
	6	---
		Implement PDCA Cycle
Training	1	Setting policy for training the operators in the industry
		Establish training system for operators
	2	Give appropriate training to all employee in industry
		Teach easier way to clean, inspect and investigate sources of contamination
	3	Establish training calendar

	4	Implement the training system for operators in the factories
		---
	5	Evaluate the activities

	6	Upgrade the skill of operators and technician
		Implement PDCA Cycle

Office TPM	1	Providing awareness to all departments in the factories
		Participation of all departments TPM activity
	2	Initial clean up of every office in the industry

	3	Fault finding work in the offices

	4	Improve the problems observed in step 3

	5	Orderly palce the items files and documents

	6	Check the items correctly
		Implement PDCA Cycle
Safety, Health and Environment	1	Constitute a committee for safety and environmental factors of the factory
		Check functioning of safety devices in the factories
	2	Prepare data analysis for accident control
		Make management control for safety
	3	Include key safety procedures
		Standardize human procedures
	4	Consder every safety problem
		Increase the knowledge of operators
	5	Conduct safety training

	6	Develop confidence
		Implement PDCA Cycle
Initial Control of Plant and Equipment	1	Defining intial control of job flow for products
		Extracting problems in present flow
	2	Set test manufacture test run and initial control period
		Establish basic system for initial control
	3	Extract problems in each intial control
		Analyze troubles in each intial stage
	4	Apply design, manufacturing and quality attitude of initial flow control
		---
	5	Develop cooperation among different departments

	6	Intial flow control audit
		Implement PDCA Cycle

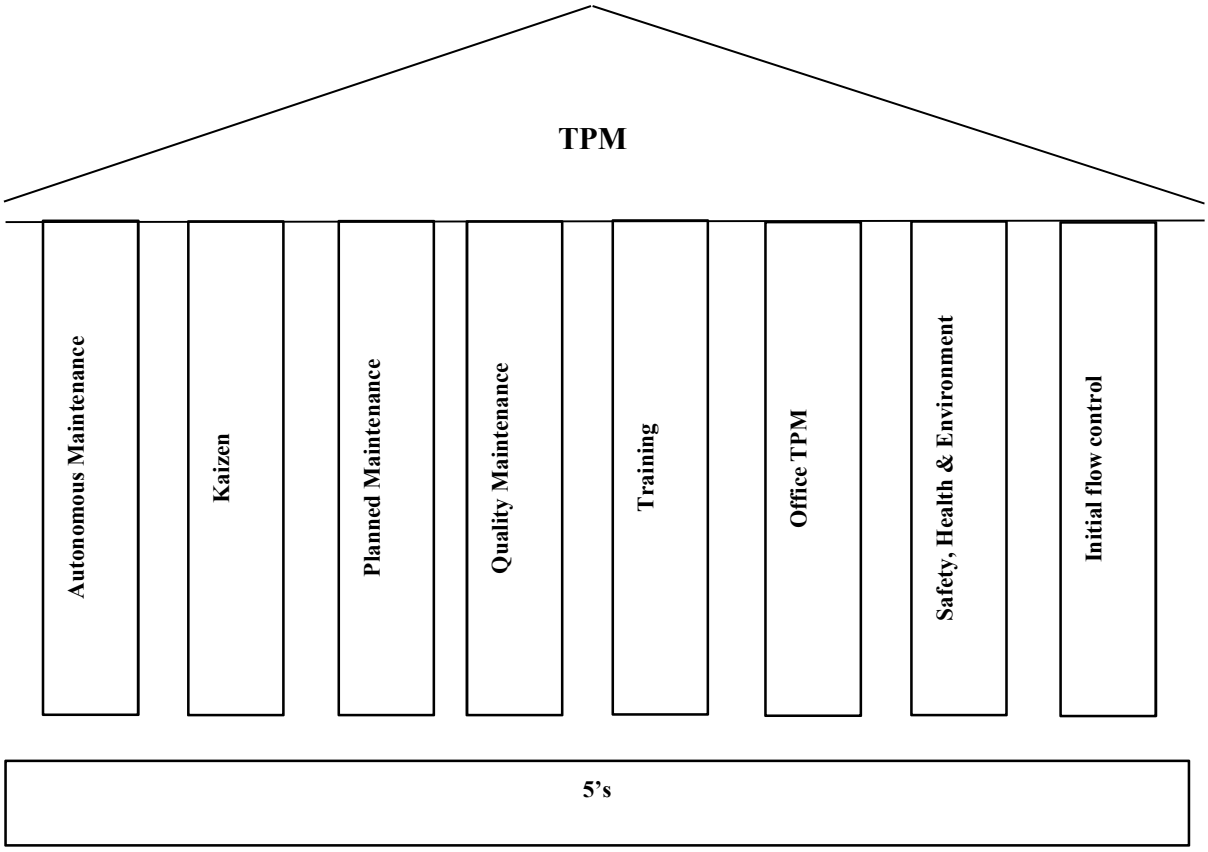

Figure 2.4 : TPM Structure

2.8.1 5S practice

The 5S practice is a preparatory phase of TPM which is a technique used to establish and maintain quality environment in an organization. A well organized workplace motivates people, both on the shop floor as well as others. 5's improves safety, work efficiency, improves productivity and establishes a sense of ownership. The 5's is developed in Japan for work place organization and house keeping and represents for Japanese words: *seiri, seiton, seiso, seiketsu* and *shitsuke* which connote Organization, Tidiness, Cleaning, Standardization and Discipline respectively .

Seiri *Sort out***:** This is to remove what is not needed and to keep what is needed in the nearby and items that are not needed in the near future in the appropriate way so that items can easily be accessible.

Seiton *Organizing*: To organize and place items in a reachable way to reduce search time. The concept is that "A place for everything and every thing in its right place". Items are marked to identify easily.

Seiso *Cleaning*: Every employee participate and responsible for cleaning working place around them. Things kept clean and polished; no trash or dirt and no leakage in the workplace. Cleaning working area create feeling of freshness and vividness.

Seiketsu *Standardization*: Developing standards for cleaning the work place for whole organization to keep neat and clean. It encompasses both personal cleanliness and the cleanliness of the environment. It is implemented after the above 3's principles practiced well in the organization to maintain the practice.

Shitsuke *Self discipline*: The main principle of *shitsuke* is to repeatedly practice the above 4's so that they become habit to every employee. This activity helps the employee to adhere to the standards and rule.

Once fully implemented, the 5's process can increase morale, create positive impressions on customers, and increase efficiency and organization. Employees will feel better about where they work and transforms the physical environment of the work area which makes the organization more profitable and competitive in the market place (Ravikant V. Paropate, Vol. No. 6 Issue No. 2).

2.8.2 Autonomous Maintenance (Jishu Hozen)

As pointed out in the previous section, autonomous maintenance is a unique feature of TPM that aimed at developing machine operators to become responsible for maintaining of their equipment, taking care of routine maintenance tasks, and elimination of production defects at source. It is one of the eight pillars of TPM which the operators participates in improvement and maintenance activities by inspecting, lubricating, replacing simple parts, minor repairing and precision checking to keep the equipment in good condition. These require the operator to be able to sense and find abnormality of the equipment (Hemant Singh Rajput, Pratesh Jaswal, Vol. 2 Issue 6) .

To acquire the above mentioned ability, operator should have the following basic abilities.

1. Ability to tell normality from abnormality precisely.
2. Accustomed to strictly keeping the rules of condition control.
3. Ability to take quick & proper actions against the abnormality.

Steps in Autonomous Maintenance:

Step 1: Create Motivation and Awareness about abnormalities in equipment & safety.

Step 2: All round clean up of dust and dirt near equipment, discover abnormalities and implement lubrication to machine parts.

Step 3: Prevent causes of dust and dirt, improve places which are difficult to clean and lubricate.

Step 4: Prepare tentative standards for clean up, lubrication and machine parts adjustment.

Step 5: Prepare inspection manuals, expose and restore equipment defects.

Step 6: Prepare and implement autonomous maintenance check lists.

Step 7: Standardize management items, logistics, data records, tool management and process quality assurance.

Step 8: Analyze and improve MTBF.

2.8.3 Kaizen

Kaizen is a Japanese word which means 'improvement' that aimed at incorporating a number of small continuous improvements to achieve and sustain zero losses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. Just as lean manufacturing relies on kaizen or continuous improvement; continuous reevaluation of the maintenance cycle allows for kaizen in maintenance programs. The key aspect of kaizen is that it is an ongoing, never ending improvement process through eliminating losses using all techniques for kaizen and by changing the operation process to make the job more productive, less tiring, more efficient or safer for the employee (Ravikant V. Paropate, Vol. No. 6 Issue No. 2).

2.8.4 Planned Maintenance

The Planned Maintenance aims to increase mean time between failures (MTBF), reduce mean time to repair (MTTR), and reduce maintenance cost. There are two basic activities carried out in planned maintenance system to have trouble free machines and equipment's producing defect free products for total customer satisfaction.

-*Maintenance activities*: It included all activities carried out to fix and prevent failures through planned and unplanned maintenance system.

-*Kaizen activities*: This includes activities carried out to extend life span, shorten maintenance time, and avoid maintenance by applying the concept of Corrective Maintenance and Maintenance Prevention (figure 2.5.)

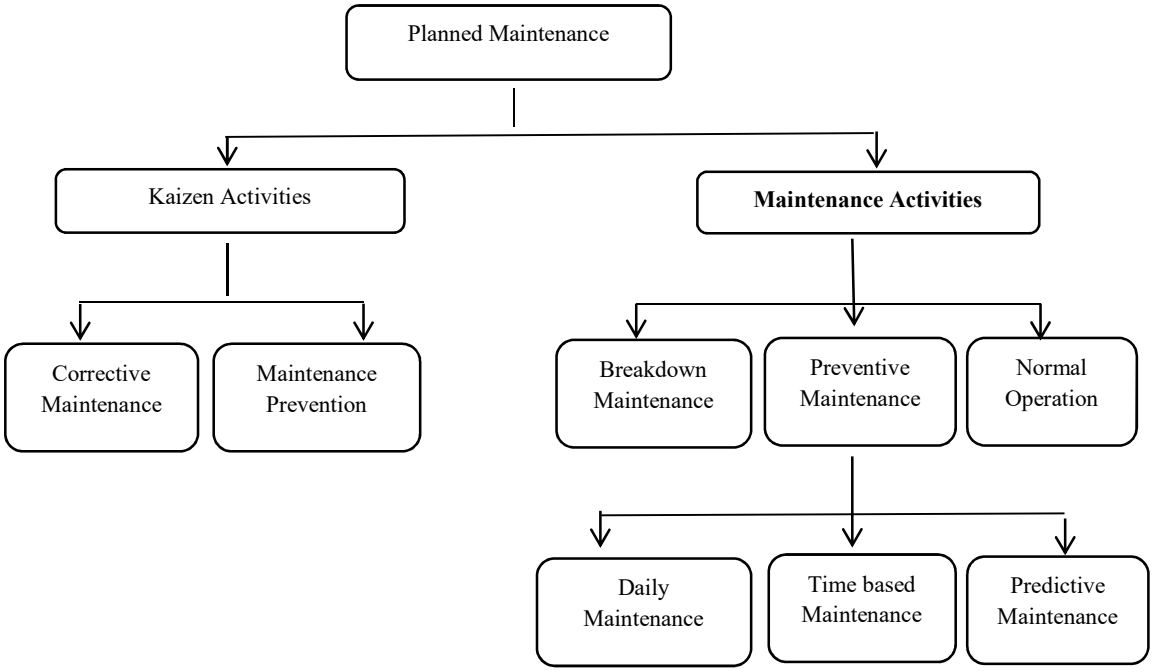

Figure 2.5: Classification of Maintenance activities

Planned maintenance has 8 activities conducted by maintenance department [4].

1. Support and guidance to Autonomous Maintenance
2. Zero Failure Activities
3. Planned Maintenance Structure
4. Lubrication Management
5. Spare Parts Management
6. Maintenance Cost Management
7. Predictive Maintenance and diagnostic method
8. Enhancement of Maintenance Technology and Skill

Preventive maintenance is periodic inspection to detect conditions that might cause breakdowns, production stoppages, or detrimental loss of function combined with maintenance to eliminate, control or reverse such condition in their early stages. In other words, preventive maintenance is the rapid detection and treatment of equipment abnormalities before they cause detects or losses. It is preventive medicine for equipment.

Preventive maintenance consists of two basic activities:
1) Periodic Inspection and
2) Planned restoration of deterioration based on the results of inspection.

2.8.5 Quality Maintenance

The purpose of Quality Maintenance is to produce defect free products to maintain the product quality through eliminating non conformance so as to satisfy the demand of the customer. *The JIPM define Quality Maintenance as* activities that are to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products (Hemant Singh Rajput, Pratesh Jaswal, Vol. 2 Issue 6) . The conditions are checked and measured in time series to verify that measured values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take counter measures before hand.

Built in quality with equipment can be accomplished by:

-Establishing an equipment state which perfectly eliminates forced deterioration and in which only natural deterioration progresses.
-Becoming proficient in equipment from managers to operators.
-Elimination of forced deterioration.
-To foster the workers' proficiency in equipment operations and maintenance.
-Equipment zero failures.
-Maintenance Prevention design of new products and new equipment.

2.8.6 Training

According to Martin M. Broadwell one of the obvious reasons for training is that the employee can't do something that the job requires to be done. He explains that there is some skill they have yet to perfect or acquire, or some knowledge they are lacking that keeps them from doing a completely satisfactory job. This reasons enough to make training a necessity. Training is an integral part of TPM. Training the operators and the maintenance workers helps to achieve zero breakdowns as many breakdowns are a result of lack of skill . This will enable the operators to maintain their own machines, understand why failures occur and suggest ways of avoiding the failures occurring again. The JIMP summarizes the ability that is required from the operator and the maintenance workers as below:

Ability: Most Wanted from operators

-Ability to find and improve equipment minor defects sources.
-Understand equipment function and mechanisms and have the power to find the cause system of troubles.
-Understand relationship between equipment and product quality and have power to predict problems with quality and to find cause systems.
-Can repair.
-Can perform individual kaizen of themes matching operator job independently or in cooperation with related department.

Ability: Most Wanted from maintenance Men

-Can instruct the correct operation and daily maintenance of equipment.
-Can judge if equipment is operating normal or abnormal.
-Can analyze abnormal condition cause and can select and implement correct restoration method.
-Can enhance equipment and part reliability, extended life and suppress abnormal condition of failures.
-Can enhance equipment maintainability by such as unit exchange and can shorten repair and restoration time.
-Have technological power to diagnose equipment and can utilize and standardize it.
-Can pursue economy in these activities and optimize them.

2.8.7 Office TPM

This pillar involves other functions of the organization to focus on improving productivity, bringing better efficiency in administrative function and eliminating losses. The aim of TPM office is to make the production system efficient through the entire organizational activity. Supportive function process information from a special stand in functional fields of the production system and provide necessary support to the production activities and other departments to reduce cost and to build up competitive power. Office TPM addresses twelve major losses. They are:

1. Processing loss
2. Cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventories
3. Communication loss
4. Idle loss
5. Setup loss
6. Accuracy loss
7. Office equipment breakdown
8. Communication channel breakdown, telephone and fax lines
9. Time spent on retrieval of information
10. Non availability of correct on line stock status
11. Customer complaints due to logistics
12. Expenses on emergency dispatches/purchases

2.8.8 Safety, Health and Environment

The basic principle of safety, health and environment is to minimize the number of accidents, health problems and damage to the environment. This pillar plays a great role in the other pillars that addresses workplace organization and discipline, regular inspections and servicing, and standardization of work procedures.

2.9 Traditional measures of manufacturing performance

The traditional measures of manufacturing performance focused on three issues)Rich, 1999):

*Asset utilization which was targeted at 100 % or the highest possible level to ensure that the production time was maximized and that a stream of products could be placed in the distribution channel to the customer.

*Labor utilization was also set at 100% or the maximum to ensure that the ligions of personnel were occupied making products for the amount of time they spent in the factory. This was often linked to the financial remuneration of employees through the piece rate system and focused the minds of everyone in the factory on "output .

*Low material costs and usage : This meant that the costs of materials were kept low maximizing the use of all materials within the conversion process and through adversarial purchasing regimes (buying from the lowest piece-part-price supplier) .

These traditional measures of manufacturing performance are counter to the objectives of TPM. It allows for a culture to be developed which is insular and detached from the commercial requirements of the business (Rich, 1997) .

The traditional measures must be changed to measures which are aligned to the conversion process with the commercial goals of the organization so that the organization becomes a world-class manufacturing company. According to Todd (1995:3), world-class simply means being the best and "best" can be in terms of:

*Product design and performance

*Quality and reliability

*Least manufacturing cost

*The ability to continuously introduce innovative designs more quickly than competitors

*Shorter lead times and more reliable delivery performance

*Customer service

It is this holistic approach that has enabled some organizations to achieve market dominance over traditional manufacturers.

2.10 Current measures of manufacturing performance

In the current study , the researcher is measuring manufacturing performance at the plant level . The measures for overall financial measures of plant performance are not appropriate since the plant does not control sales or costs. The measures of manufacturing performance which are appropriate for this study are as follows:

*Cost : This is the economic coast associated with inventories as well manufacturing cost measured as a percentage of sales. A high inventory turnover ration indicates a low cost position.

*On-time deliveries and speed of delivery performance are measures which are indicative of a plant's ability to deliver quickly and as promised.

*Quality : In this instance, conformance to quality is considered.

*Flexibility : This reflects an organisation's capability to make changes.

Use of these measurements can be traced to Schroeder (1993) and Ward at al. (1995). These authors support TPM's positive influence and its ability to enhance the technology base of the organization which leads to improved manufacturing performance. TPM can improve the technological base of an organization by enhancing equipment technology and improving the skill of employees.

TPM, when part of a world-class manufacturing strategy that incorporates JIT (Just-In-Time) and TQM also leads to improved manufacturing performance. The relationship between JIT and TPM is clear. JIT's emphasis on waste reduction creates an environment where inventory is reduced, production processes are inter dependent and the plant operation is less susceptible to breakdowns of the process.

TPM provides dependable equipment, reduces the number of production disturbances and increases plant capacity by providing effective equipment maintenance (Mcklone et al, 2001).

Todd (1995:44) summarise the key elements of JIT as :

*Existing fundamental problems and putting them right, once and for all, so that they do not keep recurring (instead of holding extra stocks "just in case" things go wrong).

*Reducing manufacturing throughput times, effectively replacing traditional batch production with continuous processing through the use of cell manufacturing and set-up reduction techniques.

*Improving supplier performance to stop material problems interfering with the organisation's ability to satisfy its customers' requirements.

*Improving quality because shorter lead times and lower stocks mean that ah organization can no longer have protection against things going wrong .

*Improving labour flexibility through cross-training so that the organization is able to deal with the fluidity of customer demand .

Reducing lead times is one of the most important ways to improve competitive edge (Todd, 1995). From the above, it is clear that TPM indirectly influences manufacturing performance by supporting the JIT concept.

2.11 Benefits of TPM

Johansson and Nord depicted the following benefits derived from the implementation of TPM :

**Productivity* is improved through fewer losses in the company.

**Quality* is also improved as a result, that the failures and malfunctions are reduced and the order and method are focused.

**The cost* are lower, because the losses, and other not value generating work are reduced.

**The delivery* time can be kept better, because the production without disturbances is easier to plan.

**Environment and security* are better, because leakages are tightened.

**Motivation* is higher, because the responsibility and rights are delegated and the investment in the personnel is done, in the form of education.

Direct benefits :

*Increase productivity and obtain a minimum of 80% Overall Plant Efficiency (OPE) and minimum of 90% of Overall Equipment Effectiveness (OEE) .

*Rectify customer complaints

*Reduce manufacturing cost by 30% .

*Satisfy customer's needs by 100% (delivering the right quantity at the right time, in the required quality.

*Reduce accidents.

*Follow pollution control measures.

Indirect benefits :

*Higher confidence levels among the employees .

*A workplace which is clean, neat and attractive.

*Achievement of goals by working as a team.

*"Ownership" of the machine by workers.

2.12 Summary

In conclusion, TPM provides a comprehensive company-wide approach to manufacture to maintenance management, which can be divided into long term and short term elements (Mcklone et al, 2001).

In the long term, efforts focus on new equipment design and elimination of sources of lost equipment time and typically require the involvement of many areas of the organization .

In the short term, TPM activities include an autonomous maintenance programme for the production department and a planned maintenance programme for the maintenance department. In this study, the researcher focuses on the short-term efforts.

TPM approach has been shown to share many common features with TQM , JIT and lean manufacturing. TPM can be seen as the extension of the world-class manufacturing techniques or programmes.

The fundamental measure of TPM was also defined as the OEE value and the seven driving forces of TPM, which provide direction for improvement based activities within manufacturing organisations, were also discussed. Measures for manufacturing performance were also considered ad it was shown that these support an organisation's internal rate of change as well as focus business improvements in line with commercial requiremnents.

Through the literature review, TPM has been defined as a strong contributer to the strength of the organization and has the ability to improve manufacturing performance. World-class manufacturing techniques such as JIT, TQM AND TPM are closely related and when combined, can increase manufacturing performance.

With competition in manufacturing industries rising relentlessly, TPM can be used as a philosophy to help prevent the failure of an organization. Furthermore, TPM helps to improve the organisation's capabilities by enhancing the problem-solving skills of team members.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The purpose of this chapter is to explain the research design and methodology that has been proposed to reach the conclusion of the research topic. The research process and the role of concepts are discussed.

3.2 Definition of research

Research is a process of planning, executing and investigating in order to find answers to our specific questions (Ghauri & Gronhaug, 2002:3). Leedy (1997:5) defines research as a process through which we attempt to achieve systematically and with the support of data, answer to a question, resolution of a problem, or a greater understanding of a phenomenon. The above serves to confirm that the researcher has to establish an appropriate strategic research design and this should come up with a n approach that allows for answering the research problem in the best possible way – within the given constraints (Ghauri & Gronhaug, 2002:47) .

3.3 Research design and sampling plan

Ghauri & Gronhaug (2002), define research design as the overall plan for relating the conceptual research problem to relevant and practicable empirical research. Empirical research is conducted to answer or enlighten research questions.

On the other hand, Leedy (1997:93) defines research design as the visualization of the data and the problems associated with the employment of those data in the entire research project as well as common sense and the clear thinking necessary of the management of the entire research endeavor.

With the stated definitions, one sees that problems may vary in structure, i.e. how well they are understood. Based on the problem structure, (Ghauri & Gronhaug ,2002:48) distinguish between the following types of research designs :

Research design	**Problem structure**
Exploratory	Unstructured
Descriptive	Structured

3.3.1 Exploratory research design

When the research problem is not properly understood , that is qualitative and unstructured, a more or less exploratory design is adequate. This type of research rarely uses questionnaires, large sample and probability plans. The focus of the research may thus shift as new insights are discovered .

3.3.2 Descriptive research design

In this type of research, the problem is quantitative in nature, structured and well understood. The key characteristics of descriptive research are structure, precise rules and procedures. The assumption in this type of research is that relevant secondary is not available and the researcher plans to collect data by a survey using personal interviews . A detailed plan must be made with regard to how many and whom to interview , That is sampling plan.

The researcher must also construct questions and make procedures on how the interviews should be conducted and questions reported. All interviews should be conducted the same way, i.e. the variation in the data collection should be as small as possible (Ghauri & Gronhaug 2002) .

3.3.3 Improving measurements

According to Ghauri & Gronhaug (2002:72), descriptive research as well as exploratory research measurwemnts can be improved by :

*Elaborating the conceptual definitions and specifying the domain constructs to be used.

*Developing adequate operational definitions (measures).

*By correcting and refining the measures.

*Evaluating the reliability and construct validity by pre-testing the measures.

*Using the final measurement in the study .

From the above discussion, it follows that the questionnaire design is closely related to measurement.

3.4 Research method and Methodology

Ghauri & Gronhaug (2002:85) refer to research method as a systematic, focused and orderly collection of data for the purpose of obtaining information from them, to solve / answer research problems or questions. A range of data sources are available from **Secondary** as well as **Primary** research sources.

In view of certain disadvantages of secondary research source, the researcher opted for primary source for research

Dunsmuir and Williams (1992), state the most common primary research sources are :

*Social surveys : (i) Questionnaire surveys (ii) Interviews : Informal or structured
*Observation

The methodology followed to pursue this research and the Overall Thesis Development Strategy is shown in table 3.1 below.

Table 3.1 : Methodology used for the overall development strategy of Thesis

Task No.	Activity
1	Literature review
2	Assessing the existing maintenance system of the industry.
	*Overall activities of the industry
	*Maintenance polocies of the industry.
	*The existing maintenance workshop facilities, capacities & workflows.
	*Repair cost, man-hour & maintenance hour.
	*Maintenacnce planning & control system.
3	Developing the master plan for the implementation of TPM
	Assessing the company's future business environment
	*Diversification of the markets & services.
	*The future plan of the company
	*The demand of the customer.
4	The need for equipment directed management developing TPM
5	Establishing TPM promotion organizational model
6	Developing user interface software

3.5 Research surveys and interviews

Ghauri & Gronhaug (2002:93) define surveys as amethod of data collection that utilizes or interview techniques for recording the verbal behaviour of respondents. The surveyu is an effective tool for collecting opinions, attitudes and descriptions as well asd for getting cause –and-effect relationships.

In research, two types of interviews are used. The first is survey research or structured interviews, where, according to Ghauri & Gronhaug (2002:100), a standard format of interview is used with an emphasis on fixed response categories and systematic sampling and loading procedures combined with quantitative measures and statistical methods. The second type is unstructured interviews, where a respondent is given almost full liberty to discuss reactions, opinions and behaviour on a particular issue.

3.6 Questionnaire design

The major issues were highlighted from the literature and considered for inclusion in the questionnaire. The questions were laid out in such a manner as to cover all aspects of TPM That had been identified as being important from the literature survey. The questions probed the respondents' understanding of Total Productive Maintenance .

The questionnaire (Scaled) shall be used in conducting the survey of all level employees at the industry under study.

According to Ferreira (2005), a scales question in one where the multiple choice alternatives give some idea of a progression in size or order of something. The researcher use the Likert

scales which are used to get people's attitudes by asking them the extent of their agreement or disagreement with a series of statements about something.

3.7 Proposed Actual survey

After completing the questionnaire, an appointment with the respective manager of the plant shall be taken to discuss the planned survey as per the policies and facilities of the plant available for the researcher to undertake the study.

3.8 Summary

In this chapter, the research design and methodology for the study of the impact of total productive maintenance at an industry is explained . A literature survey was also undertaken to look into the research process and the questionnaire design. It was also noted that questionnaires shall be utilized to a sample of selected employees across all levels of the plant. The research designs were also detailed for the researcher to choose from .

This study has exploited various research methodologies by exploring their contribution toward the best triumph of the anticipated results. Fig.1 shows different steps in developing the research. Relevant primary data and secondary data was congregated to induce superior maintenance system for the industry. The relevant secondary data was collected from the technical manual, monthly and annual report of the industry. Information was also gathered using questionnaire and interview in structured way besides direct observation on site visit to enable the investigator to keep tracking the responses.

The research begins with conceptual literature study to develop and structure suitable questionnaire and ways of interview. The literature is also reviewed side by side with data acquired from interviews and observations to develop better maintenance system to the industry. The collected data mainly aims at assessing the existing maintenance system and the future business plan of the industry. Besides, the data is synthesized with literature for investigating the potential area of improvement as shown in table 3.1.

Data analysis in the research has been conducted using appropriate tools in order to identify core problems in the specified company. Based on the analysis, for various maintenance activities of the industry some work flow and systems are developed and proposed. More over a friendly user interface computer program developed for executing the implementation program. Finally, Total Productive Maintenance system may be developed along with its implementation and master plan for the industry.

CHAPTER 4

TPM IMPLEMENTATION METHODOLOGY

4.1 Introduction

In a non-TPM organization, a lot of changes are invited in order to have a full-blown TPM system. So, it cannot be attained overnight. Depending on the size of the organization in terms of number of equipment, complexity of equipment handling, and availability of skilled manpower, it takes 1-3 years to create a "total" TPM organization. However, a strategic plan is required for its proper implementation. The major elements of its implementation in order are the understanding and development of awareness about TPM, identification and classification of problems, development of human resources and formation of small groups, collection of data on losses and flow of information, identification of engineering methods for their minimization, implementation of those methods and evaluation by statistical analysis and interpretation, documentation, and measures for further improvement.

Following are the twelve steps for the implementation of TPM :

Step 1: Announcement of TPM

Top management needs to create an environment that will support the introduction of TPM. Without the support of management, skepticism and resistance will kill the initiative.

Step 2: Launch a formal education program.

This program will inform and educate everyone in the organization about TPM activities, benefits, and the importance of contribution from everyone.

Step 3: Create an organizational support structure.

This group will promote and sustain TPM activities once they begin. Team-based activities are essential to a TPM effort. This group needs to include members from every level of the organization from management to the shop floor. This structure will promote communication and will guarantee everyone is working toward the same goals.

Step 4: Establish basic TPM policies and quantifiable goals.

Analyze the existing conditions and set goals that are SMART: Specific, Measurable, Attainable, Realistic, and Time-based.

Step 5: Outline a detailed master deployment plan.

This plan will identify what resources will be needed and when for training, equipment restoration and improvements, maintenance management systems and new technologies.

Step 6: TPM kick-off. Implementation will begin at this stage.

Step 7: Improve effectiveness of each piece of equipment.

Project Teams will analyze each piece of equipment and make the necessary improvements.

Step 8: Develop an autonomous maintenance program for operators.

Operators routine cleaning and inspection will help stabilize conditions and stop accelerated deterioration.

Step 9: Develop a planned or preventive maintenance program.

Create a schedule for preventive maintenance on each piece of equipment.

Step 10: Conduct training to improve operation and maintenance skills.

Maintenance department will take on the role of teachers and guides to provide training, advice, and equipment information to the teams.

Step 11: Develop an early equipment management program.

Apply preventive maintenance principles during the design process of equipment.

Step 12: Continuous Improvement –

As in any Lean initiative the organization needs to develop a continuous improvement mindset

CHAPTER 5

CONTRIBUTIONS OF TPM TOWARDS IMPROVING MANUFACTURING PERFORMANCE

5.1 Importance of manufacturing performance

Manufacturing is considered to be an important element in a firm's endeavor to improve firm Performance (Skinner, 1982; Hayes & Wheelwright,1984). TPM is a highly structured approach, which uses a number of tools and techniques to achieve highly effective plants and machinery. With competition in manufacturing industries rising relentlessly TPM has proved to be the maintenance improvement philosophy preventing the failure of an organization (Eti et al., 2006). Today, an effective TPM strategy and programs are needed, which can cope with the dynamic needs and discover the hidden but unused or under utilized resources (human brainpower, man-hours, machine-hours). TPM methodology has the potential to meet the current demands. A well conceived TPM implementation program not only improves the equipment efficiency and effectiveness but also brings appreciable improvements in other areas of the manufacturing enterprise.

Kutucuoglu et al. (2001) have stated that equipment is the major contributor to the performance and profitability of manufacturing systems. (Seth & Tripathi 2005) have investigated the strategic implications of TQM and TPM in an Indian manufacturing set-up. (Thun 2006) has described the dynamic implications of TPM by working out interrelations between various pillars of TPM to analyze the fundamental structures and identifies the most appropriate strategy for the implementation of TPM considering the interplay of different pillars of this maintenance approach. (Ahuja & Khamba 2008a) have investigated the significant contributions of TPM implementation success factors like top management leadership and involvement, traditional maintenance practices and holistic TPM implementation initiatives towards affecting improvements in manufacturing performance in the Indian industry.

CHAPTER 6

OVERALL EQUIPMENT EFFECTIVENESS (OEE)

6.1 Purpose of OEE

The goal of the TPM is to maximize equipment effectiveness. OEE provides an effective way of measuring and analyzing the efficiency of a single machine/cell or an integrated manufacturing system. The six major losses that can result from faulty equipment or operation, whose elimination is the major objective of the TPM, are as shown in Table 1, can results in a dramatic improvement in the Overall Equipment Efficiency (OEE). The calculation of OEE is performed by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products.

OEE= Availability (A) x Performance Efficiency (P) x Rate of Quality

It provides a systematic method for establishing production targets, and incorporates practical management tools and techniques in order to achieve a balanced view of process availability, performance efficiency and rate of quality .As stated earlier that an overall 85 percent benchmark OEE is considered as world-class performance. However, it is desirable to find the gaps between the existing performance levels and desired performance levels. Calculating the OEE following mathematical models (Sohal et.al. 2010) is adopted. The high level of effectiveness OEE will be achieved only, when all the three indexes are very high. OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products expressed by (Jostes and Helms 1994):

Availability

The available time can be defined as the time of production to operate the equipment minus the other planned downtime like breaks, meetings etc. The down time can be defined as the actual time for which the equipment is down for repairs or changeovers. This time is also sometimes known as the breakdown time. The output of this formula gives the true availability of the equipment. This value is used also in the overall equipment effectiveness formula to measure the effectiveness of the equipment. The availability is calculated as the required available time minus the downtime and then divided by the required available time.

This can be written in the form of formula as (Almeanazel, 2010 and Afefy, 2012) :

Availability = (Total Loading time – Total downtime) / Total Loading Time x 100

Performance Efficiency

The performance efficiency can be defined as the ideal or design cycle time to produce the item multiplied by the output of the equipment and then divided by the operating time. This will give the performance efficiency rate of the equipment. The formula to calculate the performance rate can be expressed as (Gomaa, 2003):

PE= Total Actual Amount of Product / Target amount of Product x 100

Quality Rate

The quality rate can be expressed as the process quantity minus the volume or number of defective quantity then divided by processed quantity. The quality rate can be expressed in a formula as (Chana et al., 2005):

Quality Rate = (Processed Quantity – Defective Quantity) / Processed Quantity x 100

Where, the quality defects mean the amount of products which are below the quality standards i.e. the rejected items after the production process. This formula is very helpful to calculate the quality problems in the production process (Mobley, 2002).

World Class OEE :

Table 6.1: Percentage of World Class OEE

OEE Factors	OEE World Class
A %	90.0 %
PE %	95.0%
QR %	99.9 %
OEE %	85.0%

World class OEE is a standard which is used to compare the OEE of the firm. The percentage of World Class OEE is given in Table 6.1(Kailas, 2009).

CHAPTER 7

CALCULATION OF OVERALL EQUIPMENT EFFECTIVENESS (OEE)

7.1 Methodology of Calculation of OEE

Overall Equipment Effectiveness has been developed by the JIPM. OEE is regarded as an important measurement for assessing the performance of equipment. The method distinguishes the six big loss types, and three key performance measurements: availability, performance rate and quality rate that combines into one consolidated metric. The OEE can be used to help focus on improving the performance of machinery and associated processes by identifying those performance opportunities that will have the greatest impact to the bottom line. Improvements in changeovers, quality, machine reliability, working through breaks and more, can be measured and improved utilizing the OEE metric. It is the ratio of actual equipment output to its theoretical maximum output. OEE can be viewed as the percent of time that equipment would need to run at its maximum speed in order to attain the actual output of that tool or machine.

It is calculated using the following formula.

OEE = Availability x Performance Rate x Quality Rate

To find the overall equipment efficiency of the Industry, identifying the six major losses of the machines was the first stride by organizing under three key factors. And then data pertinent to those losses was collected for randomly selected machineries. The major losses that are identified and the OEE of the selected machineries presented as follows.

Calculating Overall Equipment Effectiveness (OEE)

Some of the data pertinent to the above loss are difficult to obtain, since the company doesn't apply the overall equipment efficiency concepts in evaluating the performance of the machines at the individual level. It has been attempted to gather some relevant data to estimate the OEE of the typical machinery.

Availability

The availability is the ratio of time needed for operating the equipment to the time actually consumed for operation and it is expressed as:

Availability = (Actual Running Time / Scheduled Running Time) x 100

Where

Actual Running Time = Scheduled running time – Unplanned stoppages.

Unplanned stoppage means the period during which the line is stopped due to equipment failure, setup, adjustment, and change over and so forth. So that:-

Availability = (Scheduled Running Time – Unplanned Stoppage) / Scheduled Running Time x 100

Performance Rate

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear. Hence, it is expressed as:

Performance Rate = (Actual average production / Standard production) x 100

Average production rate = Total Production in a cycle period / No. of working days in a cycle period

Quality Rate

This is percentage of good parts out of total produced sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:

Quality Rate = (No. of products processed – No. of products rejected) / No. of products processed x 100

CHAPTER 8

PLAN OF THESIS WORK

8.1 Plan of Proposed Thesis work

It is expected that the study will be completed within three year time frame proposed foer the PhD programme as timed below:

Table 8.1 : Plan showing the action plan for completion of Thesis work

Step	Activity	Description	Duration
1	Search	Literature search , Proposal writing	5 months
2	Course work	Relevant course work and literature review at University / Research Centre	5 months
3	Fieldwork I	Developing instruments , Research protocols, identifying and laisioning with relevant places and personnel and confirmation of work plan with Research Supervisor	3 months
4	Fieldwork II	Data collection using various instruments , appropriate sampling techniques and protocols according to the methodological and theoretical frameworks of the study	5 months
5	Fieldwork III	Data collection and follow-up to validate models , tools and strategies and their evolution , Refining research skills	7 months
6	Analysis	Data analysis, interpretation of results, draft thesis document at the University / Research center	5 months
7	Conclusion	Completion of thesis , publishing, fulfillment of other academic and institutional requirements at the University / Research centre	6 months
		Total duration = Three years (3)	36 months

CHAPTER 9

STRUCTURE OF THESIS

The outcome of the research study results into compilation of the final thesis with the documentation as detailed below chapter wise:

Chapter 1 : deals with the introduction, overview, problem statement and the scope and limitations and significance of the research

Chapter 2 : describes the literature review wherein earlier works in this area are discussed.

Chapter 3 : proposes the research design and methodology, questionnaire design

Chapter 4 : explains the TPM implementation methodology

Chapter 5 : explains the contributions of TPM towards manufacturing performance

Chapter 6 : deals with overall equipment effectiveness and its purpose

Chapter 7 : deals with the calculation of overall equipment effectiveness

Chapter 8 : proposes the action plan for the thesis work

Chapter 9 : summarizes the structure of thesis

ANNEXURE

A CASE STUDY :

Case Study for evaluating the effect of OEE before and after Implementation of TPM in a small company

About the Company :

Plastic Extrusion Pvt. Limited is a Certified Company situated in Industrial Area. Company is manufacturing Plastic Polythene Pipes of different sizes according to the demand Of customers and uses in different areas. The Materials are supplied to the company from Delhi. The Products are supplied in different areas.

The different sizes of pipes ranging from 5" dia. to 12" dia. are manufactured.

Table A1 : Dia. of pipes manufactured in industry

Sl. No.	Dia. in inches	Dia. in cm	Dia. in mm
1	5	13	130
2	6	15	150
3	7	18	180
4	8	20	200
5	9	23	230
6	10	25	250
7	11	28	280
8	12	30	300

Table A2 : Sample of Monthly Production of Pipes before TPM (Cycle period of 5 months)

Sl. No.	**Month**	**Production (Quintal)**
1	May	2200
2	June	2190
3	July	2150
4	August	2170
5	September	2100

Table A 3 : Production and Wastage before TPM (Cycle period of 5 months)

Months	Production (Quintal)	Waste (Quintal)	%
May	2200	250	11.36
June	2190	239	10.91
July	2150	235	10.93
August	2170	235	10.82
September	2100	230	10.95

V. Calculating Overall Equipment Effectiveness before TPM (First cycle period of 5 months)

Availability = (Scheduled running time – Unplanned stoppage) / Scheduled running time x 100

Where, Scheduled running time of Extruder & Electrical Control Machine (8am to 6 pm) = 10 hours (600 mins)

Unplanned stoppages 3 to 4 Times = 45 min

Scheduled running time for 1 Month = 30 days = 30 10 = 300 hours (18000 min)

Unplanned stoppages for 1 month = 45 x 30 = 1350 min

Availability = (Scheduled running time – Unplanned stoppages) / Scheduled running time x 100 = (18000 - 1350) / 18000 x 100 = 92.5 %

Performance Rate without implementation of TPM (First cycle period of 5 months)

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear. Hence, it is expressed as:

Performance Rate = Actual average production / Standard Production x 100

where, Actual average production = Total production in a cycle period / No. of working days in a cycle period

Total production of pipes manufactured in a cycle period of 5 months = 10810 Quintal

No. of working days in cycle period of 5 months = 150

Standard production = 75 Quintal per day

Actual average production = Total production in a cycle period / No. of working days in a cycle period = 10810 / 150 = 72.066 Quintal per day

Performance Rate = Actual average production / Standard Production x 100 = 72.066 / 75 x 100 = 96.088

Quality Rate (First cycle period of 5 months)

This is percentage of good parts out of total produced sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:

Quality rate = (No. of Products processed – No. of Products rejected) / No. of Products processed x 100

Output for 1 day = 75 Quintal (10hours)

Waste for 1 day = 7.9 Quintal

Output for 1 month = 2250 Quintal

Waste for 1 month = 237 Quintal

Quality rate = (No. of Products processed – No. of Products rejected) / No. of Products processed x 100 = (2250-237) / 2250 x 100 = **89.466 %**

From the above the quality rate of the Extruder And Electrical Control machine is 89.466% Therefore, the Overall Equipment Efficiency of the machine is obtained by multiplying the above three factors and the result is

Overall Equipment Efficiency (OEE) = .925 X .96 X .894 X 100 **= 79.38 %**

The calculated Overall Equipment Efficiency of the machines is **79.38 %** before TPM.

The major losses that are identified are :

1. Equipment failure loss

2. Setup and adjustment loss

3. Startup loss

4. Minor stoppage and idling loss:

5. Speed Loss

6. Quality Defect and rework loss

VI. Calculating Overall Equipment Effectiveness after TPM (Second cycle period of 5 months)

Table A4 : Sample of Monthly Production of Pipes after TPM (Second cycle period of 5 months)

Sl. No.	Month	Production (Tonnes)
1	December	2240
2	January	2250
3	February	2160
4	March	2240
5	April	2220

Table A5 : Production and wastage before TPM (Second cycle period of 5 months)

Months	Production (Quintal)	Waste (Quintal)	%
December	2240	195	8.7
January	2250	190	8.4
February	2160	170	7.8
March	2240	170	7.5
April	2220	165	7.4

Scheduled Running Time of Extruder & Electrical Control Machine (8am to 6 pm) = 10 hours (600 mins)

Unplanned Stoppages 2 to 3 Times = 35 min

Scheduled Running Time for 1 Month = 30 days = 30 x 10 = 300 hours (18000 mins)

Unplanned Stoppages for 1 month = 35 x 30 = 1050 mins

Availability = (Scheduled running time – Unplanned stoppages) / Scheduled running time x 100 = (18000 – 1050) / 18000 **= 94.166 %**

Performance Rate with Implementation of TPM (Second cycle period of 5 months)

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear. Hence, it is expressed as:

Performance Rate = Total production in a cycle period / No. of working days in a cycle period

Total production of pipes manufactured in cycle period of 5 months = 11110 Quintal

No. of working days in cycle period of 5 months = 150

Standard production = 75 Quintal per day

Actual average production = Total production in a cycle period / No. of working days in a cycle period = 11110 / 150 = 74.066 Quintals per day

Performance Rate = 74.066 / 75 x 100 = 98.755

Quality Rate (Second cycle period of 5 months)

This is percentage of good parts out of total produced sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:

Quality rate = (No. of Products processed – No. of Products rejected) / No. of Products processed x 100

Output for 1 day = 75 Quintal (10hours)

Waste for 1 day = 5.9 Quintal Output for 1 month = 2250 Quintal

Waste for 1 month = 178 Quintal

Quality rate = (No. of Products processed – No. of Products rejected) / No. of Products processed x 100 = (2250-178) / 2250 = **92.088 %**

From the above the quality rate of the Extruder And Electrical Control machine is 92.088% Therefore, the Overall Equipment Efficiency of the machine is obtained by multiplying the above three factors and the result is

Overall Equipment Efficiency (OEE) = .941 x .987 x .920 x 100 **= 85.44 %**

The calculated Overall Equipment Efficiency of the machines is **85.44%** after TPM

VI. Conclusion

The main objective of this study is to understand TPM concept and to generate awareness among the budding technologies about TPM. During research in the company comparison before implementing TPM and after implementing is made. Major problems are distorted by TPM based correction plan and 60 % of the problems were reduced by improving OEE. TPM methodology not only increases the effectiveness of the manufacturing system but also increases the effectiveness of the entire organization through mandatory participation and continuously improve Productivity, Quality, Cost, Delivery, Safety, Health and Morale .

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